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DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-78-57

HABITAT DEVELOPMENT FIELD INVESTIGATIONS SALT POND NO. 3, MARSH DEVELOPMENT SITE SOUTH SAN FRANCISCO BAY, CALIFORNIA

SUMMARY REPORT

by

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Final Report

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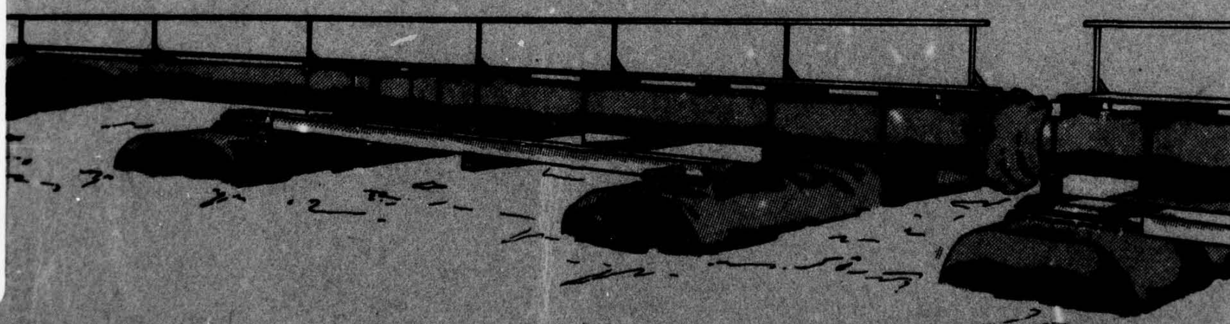

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DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
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IN REPLY REFER TO: WESEV

15 January 1979

SUBJECT: Transmittal of Technical Report D-78-57

TO: All Report Recipients

1. The technical report transmitted herewith represents the results of one of a series of research efforts (work units) conducted as part of Task 4A (Marsh Development) of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 4A was part of the Habitat Development Project (HDP) and had as its objective the development and testing of the environmental and economic feasibility of using dredged material as a substrate for marsh development.

2. Marsh development on dredged material was investigated by the HDP under both field and laboratory conditions. This report, "Habitat Development Field Investigations, Salt Pond No. 3 Marsh Development Site, South San Francisco Bay, California; Summary Report" (Work Unit 4A18), presents and discusses the activities that occurred during marsh development studies at Salt Pond No. 3 on San Francisco Bay near Hayward, California, between 1975 and 1977. Specifically discussed are the engineering and biological aspects of salt marsh propagation on consolidated clayey dredged material.

3. A total of nine marsh development sites were selected and designed by the HDP at various locations throughout the United States. Six sites were subsequently constructed. Those, in addition to Pond No. 3, include: Windmill Point on the James River, Virginia (4A11); Buttermilk Sound, Atlantic Intracoastal Waterway, Georgia (4A12); Apalachicola Bay, Apalachicola, Florida (4A19); Bolivar Peninsula, Galveston Bay, Texas (4A13); and Miller Sands, Columbia River, Oregon (4B05). Detailed design for marsh restoration at Dyke Marsh on the Potomac River (4A17) was completed, but project construction was delayed in the coordination process. Marsh development at Branford Harbor, Connecticut (4A10), and Grays Harbor, Washington (4A14), was terminated because of local opposition and engineering infeasibility, respectively.

4. Evaluated together, the field site studies plus ancillary field and laboratory evaluations conducted in Task 4A establish and define the range of conditions under which marsh habitat development is feasible.

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Data presented in the research reports conducted in this task will be synthesized in the technical reports entitled "Upland and Wetland Habitat Development with Dredged Material: Ecological Considerations" (2A08) and "Wetland Habitat Development with Dredged Material: Engineering and Plant Propagation" (4A24).

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

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A study of marsh development on confined dredged material substrate in an abandoned salt pond in South San Francisco Bay demonstrated that a California cordgrass *(Spartina foliosa)* marsh can be established within 2 years. For successful marsh development, proper elevations and tidal flow must be provided. For the San Francisco Bay area, sprigs should be planted in early spring on low wave energy sites and at 0.5- to 1.0-m intervals within the lower two-thirds of the intertidal range.

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PREFACE

This study was conducted as Work Unit 4A18 of the Dredged Material Research Program (DMRP) for the Office, Chief of Engineers, by the U. S. Army Engineer Waterways Experiment Station (WES), Environmental Laboratory (EL), Vicksburg, Mississippi. It was part of a nationwide effort by the Habitat Development Project (HDP) of the DMRP to develop, test, and evaluate the environmental, economic, and engineering feasibility of using dredged material as a substrate for marsh development. This report presents the results of an investigation of California cordgrass (*Spartina foliosa*) salt marsh development on a confined fine-grained dredged material substrate.

The initial planting operation (spring 1976) was jointly conducted by the U. S. Army Engineer District, San Francisco (SFD), and WES. Mr. Paul L. Knutson, SFD, was in charge of the field operations. Technical aspects of this operation were under the direction of EL Botanist, Dr. Luther F. Holloway, and Mr. Thomas R. Patin, EL, Civil Engineer.

Biological monitoring of the planting study was initiated in 1976 by the San Francisco Bay Marine Research Center, Inc. (MRC) for EL under Contract No. DACW07-76-C-0037. Principal investigator for this activity was Dr. Curtis L. Newcombe. Technical aspects of this contract were initially under the direction of Dr. Luther F. Holloway and Mr. Thomas R. Patin and later under EL Botanist, Dr. Robert Terry Huffman, who also initiated further propagation studies during the spring of 1977.

Thanks are expressed to all individuals who contributed to this study, particularly to Mr. John W. Walmsley and Mrs. Carol Purser of MRC. Mr. Walmsley had a major responsibility in all of the field monitoring operations. Mrs. Purser contributed greatly to the numerous report preparations and data analyses. Thanks are due to Dr. Kenneth W. Floyd and Mr. Michael Castelli, former MRC staff members, who contributed in various ways to the early phases of the project. Credit is also due Ms. Sue Fairchild and Messrs. James Brown, John Sustar, and Thomas Wakeman of the SFD, who provided much in the way of administrative support and made varied types of information readily available to the study.

The study was under the general supervision of Dr. Hanley K. Smith, Manager, HDP, Dr. Roger T. Saucier, Special Assistant, DMRP, and Dr. John Harrison, Chief, EL.

Commander and Director of WES during this time was COL John L. Cannon, CE. Technical Director was Mr. Fred R. Brown.

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HABITAT DEVELOPMENT FIELD INVESTIGATIONS, SALT POND NO. 3 MARSH DEVELOPMENT SITE, SOUTH SAN FRANCISCO BAY, CALIFORNIA

SUMMARY REPORT

PART I: INTRODUCTION

1. During the past 150 years, significant portions of salt marshes in the San Francisco Bay area have been lost, primarily through conversion of wetlands to commercial, residential, and industrial uses. In recent years a major effort has been made to reclaim these wetlands and restore the deteriorating estuary. One method considered was the use of dredged material as a substrate for the development of salt marshes. This process is largely dependent upon an engineering design that achieves appropriate substrate elevations and on economically feasible techniques of planting marsh species. This report discusses a marsh demonstration study in the South San Francisco Bay area.

2. In March 1972, the San Francisco District, with authorization from the Office, Chief of Engineers, undertook a comprehensive, in-depth study on the environmental impacts of dredging and open-water disposal. Additionally, they examined alternative disposal methods to eliminate or mitigate identified problems within the San Francisco Bay area. One of the alternatives investigated was the feasibility of the development of a salt marsh habitat on dredged material. This concept was tested by the San Francisco District on unconfined fine-grained dredged material deposited along the banks of the Alameda Creek Flood Control Channel in South San Francisco Bay (Figure 1). The study demonstrated the feasibility of marsh development on unconfined fine-grained dredged material and provided valuable information on salt marsh planting techniques for California cordgrass *(Spartina foliosa)* and pickleweed *(Salicornia* spp.*)* (U. S. Army Engineer District, San Francisco 1976 and 1977).

3. In 1974, as part of the San Francisco District's Alameda Creek Flood Control Project, a 40.4-ha confined (diked) saltwater evaporation pond (Salt Pond No. 3) was filled with approximately 500,000 m^3 of fine-grained clayey dredged material. The dredged material was allowed to

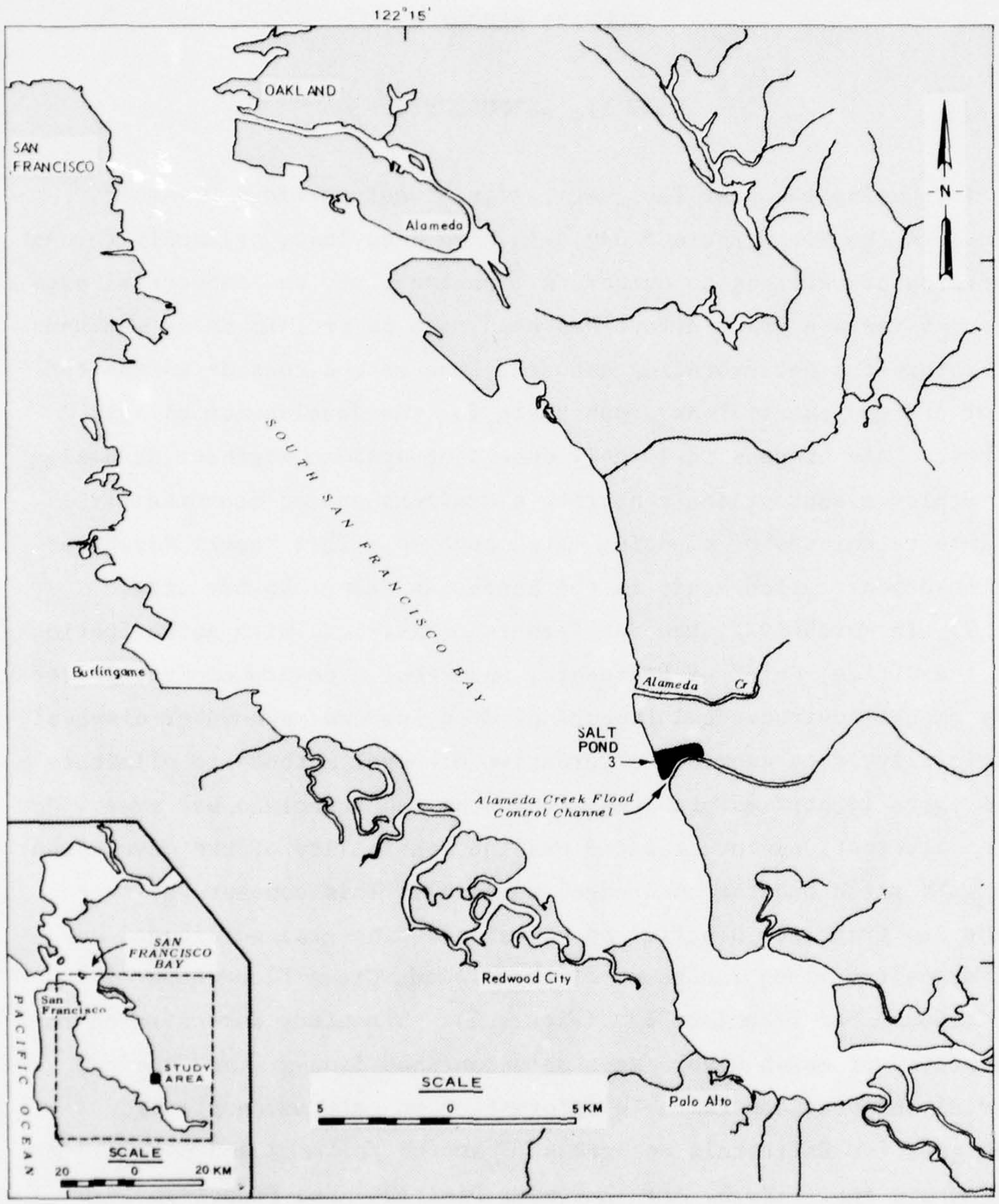

Figure 1. Location of the Salt Pond No. 3 study site within South San Francisco Bay

dry and consolidate for 2 years and was then exposed to tidal flow by constructing a breach in the bay side dike and digging intertidal drainageways (Figures 2 and 3). It was then that personnel from the Dredged Material Research Program's Habitat Development Project entered into a cooperative agreement with the San Francisco District on this study.

4. The primary objective of the Habitat Development Project was to assess the feasibility of developing aquatic, marsh, island, and upland habitats on various types of dredged material substrates. Field work undertaken at Salt Pond No. 3 was to provide information on developing a cordgrass marsh on confined dredged material. Toward these objectives, the project was concerned with five studies:

- a. The maximum distance to space propagules and obtain satisfactory cover in 2 years;
- b. The possible need for substrate preparation prior to planting;
- c. The suitable elevational range for planting;
- d. The optimal season for planting; and
- e. The efficiency of hand planting by the walk method as compared with hand planting by the tractor-assisted method.

In addition, natural colonization by plant species on the site was documented.

Figure 2. Aerial view of Salt Pond No. 3 during consolidation of the dredged material

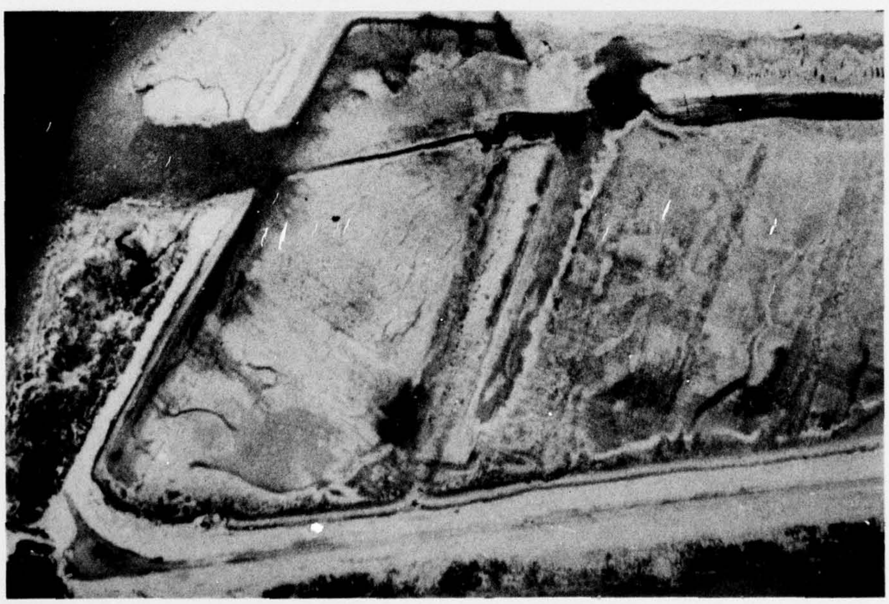

Figure 3. Aerial view of Salt Pond No. 3 after construction of the dike breach and drainageways

PART II: METHODS AND MATERIALS

5. The California cordgrass propagation studies at Pond No. 3 were all conducted in plots on confined, fine-grained dredged material. These studies, along with some information as to their design, are listed in Table 1. Study plot locations are shown in Figure 4. Both seeds and sprigs, obtained from nearby marshes, were used. Sprigs were planted at 1.0-m intervals except in the plant spacing study. The seeding rate varied from 0.004 ℓ/m^2 to 0.028 ℓ/m^2. Plant survival and shoot density were monitored in each of the studies; biomass was monitored in September 1977 in all but the elevational study. Survival of individual plants was monitored only during the first growing season; thereafter, the density of new shoots was observed. Shoot density was determined by sampling fourteen 0.75-m^2 quadrats per subplot; sample adequacy was determined for quantitative data so that a standard error no greater than 15 percent of the mean of the measured plant property occurred. Biomass data were obtained for each subplot using 0.1-m^2 clip-plots. The number of clip-plots sampled per subplot varied; sampling of each subplot was continued until the standard error of the mean wet weight of the clip-plots was less than 10 percent of the mean wet weight.

Plant Spacing Study

6. The plant spacing study (Plot A) was designed to evaluate vegetative cover 2 years after sprigs were planted at 0.5-, 1.0-, 2.0-, and 3.0-m intervals. For this, three subplots were sprigged at each of the four planting intervals and three were left unplanted as controls.

Substrate Preparation Study

7. The dredged material at Pond No. 3 was dewatered prior to introduction of tidal action. During this period, numerous wide (0.05 to 0.08 m) desiccation cracks developed and extended 0.6 to 0.9 m deep

Table 1

Propagation Studies Conducted at Salt Pond No. 3

Study	Plot*	Number of Sub-plots and Size, m	Propagule	Variables Monitored**
Plant spacing	A	15 (10 x 10)	Sprigs	Survival Shoots/m^2 Shoot density Biomass
Substrate preparation				
prepared	B	24 (3 x 25)	Seeds, Sprigs	Survival Shoots/m^2 Shoot density Biomass
unprepared	C	24 (3 x 25)	Seeds, Sprigs	Survival Shoots/m^2 Shoot density Biomass
Plant elevation	B'	12 (3 x 75)	Sprigs	Survival New shoots
Planting season	D	20 (10 x 10)	Sprigs	Survival Shoots/m^2 Biomass
Planting efficiency				
tractor-assisted method	E	2 (20 x 50)	Sprigs	Shoots/m^2 Biomass
tractor-assisted method	F	21 (20 x 50)	Seeds, Sprigs	Shoots/m^2 Biomass
tractor-assisted method	G	15 (20 x 50)	Seeds	Shoots/m^2
walk method	B	-------------See Plot B above-------------		
walk method	C	-------------See Plot C above-------------		

* Plot locations are shown on Figure 4.

** All variables not monitored throughout the studies.

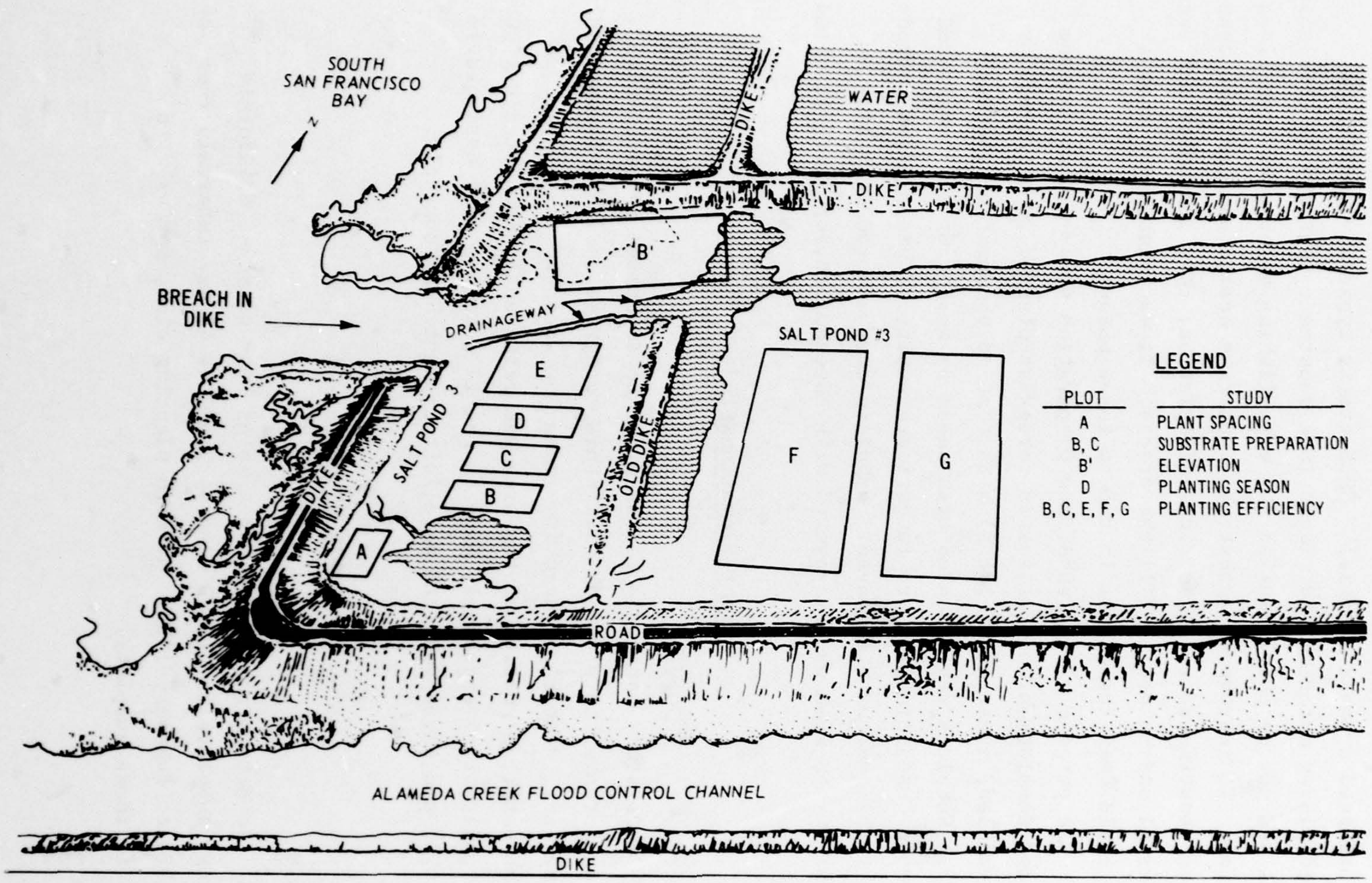

Figure 4. Diagram of Salt Pond No. 3 study site showing location of dikes, drainageways, and study plots

in the hardened dredged material. Such cracks typically develop in dewatered clayey material and result in a substrate that may be difficult to plant and may be poorly suited for establishing vegetative cover in a short time. To improve the substrate, the dike breach and drainage channels were constructed to allow tidal circulation; this gradually softened the material and helped to fill the cracks. It was also found that a tractor could seal the cracks in two to three passes.

8. The purpose of the substrate preparation study was to compare growth and development of California cordgrass planted on prepared, or tractor-sealed, substrate (Plot B) with that on unprepared substrate (Plot C). Subplots were planted with seeds or sprigs or left unplanted as controls. Additionally, to investigate substrate preparation methods, various techniques were employed: subplots were covered with biodegradable nylon mesh paper, covered with cheesecloth, or left uncovered.

Plant Elevation Study

9. This study was conducted in order to determine the suitable elevational range for planting California cordgrass sprigs. Elevations in the study area, Plot B', ranged from mean low water to slightly above mean high water; a portion of the area was permanently inundated but subject to daily tidal exchange. Nine of the 12 subplots were sprigged in March 1977, and three subplots were left unplanted as controls.

Planting Season Study

10. To determine the optimal time of year to plant California cordgrass, subplots in Plot D were sprigged at 45-day intervals from April 1976 to February 1977. At each planting time, sprigs were planted in three subplots.

Planting Efficiency Study

11. The purpose of this study was to determine time/cost requirements for two types of hand-planting operations: planting on foot (walk method) and planting from a tractor (tractor-assisted method). Seeds were planted by hand broadcasting (Plots B and C) and by a mechanical seeder mounted on a tractor (Plots F and G). Sprigs were planted by hand while walking (Plots B and C) and by hand by men on a tractor-drawn sled (Plots E and F). In addition, the study was to compare plant growth and development of propagules planted by the different operations. The mechanical seeder required two men, the tractor-drawn sled required four, and the walk method plantings were done by a team of four men.

Natural Colonization

12. A record was kept of species of vascular plants that naturally invaded the study area. The record included relative abundance and general location. Voucher specimens were also collected.

PART III: RESULTS AND DISCUSSION

13. The attempts to propagate California cordgrass by seed were unsuccessful: almost no germination (0.0075 percent) occurred on any of the seeded plots. Germination may have been inhibited by the high salinity (30-89 ppt) of the substrate or possible low viability. In general, propagation using sprigs was successful.

Plant Spacing

14. Best results were obtained with the 0.5-m spacing. This interval gave good coverage in the lower two-thirds of the intertidal range. In many cases, particularly in the lower third of the intertidal range where site conditions were better, sprigging at 1.0-m intervals produced satisfactory cover in two growing seasons. Sprigging at intervals greater than 1.0 m did not produce adequate cover during the 2-year period of this study.

Substrate Preparation

15. The study demonstrated that tractor-sealing of the substrate was not necessary. Sprigs planted on an unprepared, uncovered substrate provided a satisfactory cover in two growing seasons. Further, covering the substrate, either with biodegradable paper or cheesecloth, did not give the plants any significant advantage; after the second growing season there was no appreciable difference between those covered and those uncovered. Although sprigs in the substrate-prepared and covered subplots evidenced slightly better survival and growth after one growing season, the added cost of soil preparation and cover could not be justified.

Plant Elevation

16. The cordgrass sprigs became established relatively well in the lower two-thirds of the intertidal range, while invading species of pickleweed dominated the upper third. This zonation is typical of many marshes in the San Francisco Bay area. The less frequent tidal inundation of the upper zone probably favors establishment by pickleweed. While other high marsh species can also grow under these conditions, pickleweed is more common in the area as it is a more rapid invader.

17. In the regularly inundated, tidally flushed areas, the sprigs produced a cordgrass-dominated marsh. Colonies were absent only on sites with significant current activity, such as in the drainageway and in shallow tidal channels.

Planting Season

18. Regardless of time of planting, percent survival was generally high 6 weeks after sprigging and for most planting times, did not decline more than 10 percent from the 6-weeks period to the end of the first growing season (November). Spring-planted sprigs produced significantly more shoots than those planted later because they had a longer growing season. While spring appears to be the best time to plant sprigs, the results indicate that, regardless of planting time, California cordgrass can be expected to survive and grow well.

Planting Efficiency

19. The walk method of planting sprigs had better results than the tractor-assisted one; the survival rate was more than 50 percent higher than that of those planted from the sled. The actual reason for the difference is not known, but a few possibilities can be mentioned. First, the same persons did not plant in both operations and those sprigging by the walk method may have been more experienced. Second, it

may be that the slower walk method allowed for better care during planting, particularly in firming the substrate around the sprig. In addition, it is probable that hand planting from a sled is more awkward, requires more balance, and makes proper firming more difficult.

20. Sprigs planted by the walk method produced more new shoots than those planted from the sled. In general, they yielded about 35 percent more shoots, as would be expected since they had a significantly higher survival rate than the other group.

Cost Estimation

21. Costs for propagation are determined by man-hour requirements for procuring, transporting, and planting propagules; equipment rental and operating costs; supplies; wages; and overhead. These costs can vary greatly by site and are dependent upon the species and type of propagule, the circumstances involved in obtaining an adequate number of propagules, the planting technique, the substrate conditions, the skill of the personnel, and other factors.

22. As a guide in estimating costs, approximate man-hour requirements for obtaining and hand planting seeds and sprigs over a 1000-m^2 area at Salt Pond No. 3 are given in Table 2. The walk method required approximately 4.7 man-hours for seeding and 22 man-hours for sprigging. By comparison, the tractor-assisted work, which involved only the planting phase, required 0.06 man-hour for seeding and 1 man-hour for sprigging to plant 1000 m^2.* For the walk method, actual costs for seeding were about one-third that for sprigging. Costs were greater when tractor assistance was used, but planting time was much less.

23. The relative percentages of total costs for obtaining and planting sprigs during the Salt Pond No. 3 study are shown in Figure 5. Figure 5a shows how costs were divided for the three major expenditures:

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* At these tractor-assisted rates, 0.4 ha could be sprigged on 1.0-m centers in 4 man-hours and 1.6 ha could be seeded in 1 man-hour.

Table 2

Approximate Man-hour Requirements in Propagation Operations to Plant 1000 m^2 by the Walk Method

Operation	Seed (man-hours/2.8ℓ)	Sprigs (man-hours/1000 sprigs)
Collection	4.7	10
Preparation, Storage, Viability Test	1.3	-
Planting	4.7	22
Miscellaneous (including transportation)	included above	16
TOTAL	10.7	48

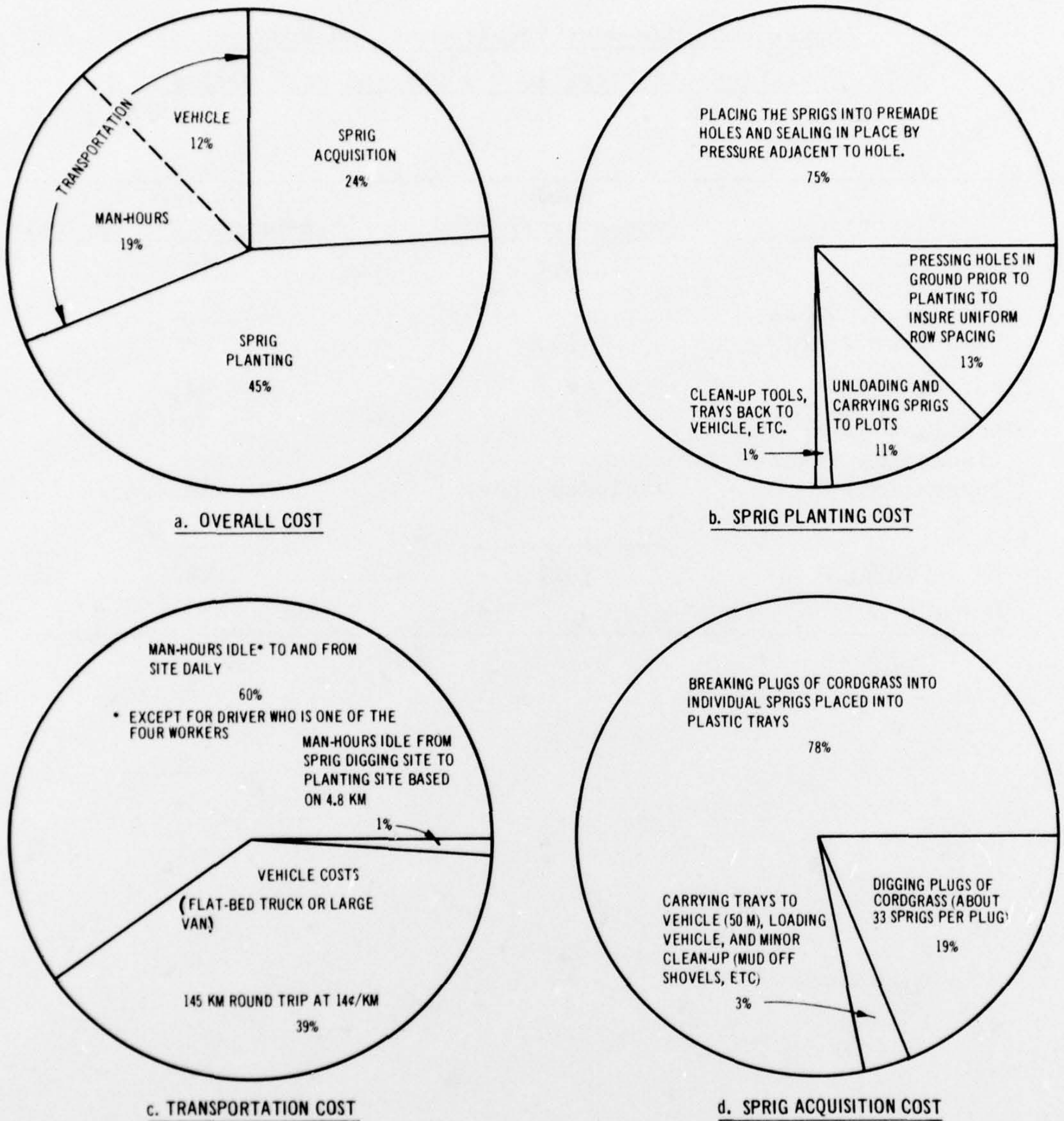

Figure 5. Relative percent cost requirements for obtaining and planting sprigs at Salt Pond No. 3

sprig acquisition, sprig planting, and transportation. Figures 5b, 5c, and 5d show the relative cost breakdown within each of the major expenditures.

Natural Colonization

24. A list of vascular plants that colonized Salt Pond No. 3 during the study, along with their estimated abundance and general location, is given in Table 3.

Table 3

Colonizing Plant Species at Salt Pond No. 3

Common Name	Scientific Name*	Abundance**	Location
Australian saltbush	*Atriplex semibaccata*	Frequent	At or above high tide on west dike
Frankenia	*Frankenia grandifolia*	Occasional	West dike
Gum plant	*Grindelia robusta*	Rare	Near SW corner
Ice plant	*Mesembryanthemum nodiflorum*	Occasional	South and west dikes
Jaumea	*Jaumea carnosa*	Rare	Near SW corner
New Zealand spinach	*Tetragonia ixpansa*	Rare	West dike
Perennial pickleweed	*Salicornia pacifica*	Frequent	High intertidal areas
Pickleweed	*Salicornia rubra*	Frequent	High intertidal areas
Saltbush	*Atriplex patula* var. *hastata*	Rare	Bay side of west dike
Saltgrass	*Distichlis spicata*	Occasional	West dike
Sand spurry	*Spergularia marina*	Frequent	High tide and higher

* Nomenclature after Mason (1969).
** Abundance estimations are:
Frequent - single plants or colonies spaced up to 15 cm.
Occasional - single plants or colonies spaced 15 to 60 cm.
Rare - single plants or colonies spaced more than 60 cm.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

25. California cordgrass marshes can be successfully developed within 2 years on confined, fine-grained dredged material substrate in abandoned salt ponds of the San Francisco Bay area. Care must be taken in the engineering and design of the site so that the proper elevation levels and intertidal flow will be achieved. It is recommended that sprigs be planted in early spring at 0.5- to 1.0-m intervals in the lower two-thirds of the intertidal area at low wave energy sites. Sprigging at these intervals should produce satisfactory cover within two growing seasons. In addition, it is not necessary to prepare the substrate, except to correct local situations such as debris removal. Sprigging is not recommended in the upper third of the tidal zone since this area is quickly invaded and dominated by species of pickleweed. Large-scale cordgrass seeding is not recommended without prior experimentation, both in the laboratory and in the field, to determine seed viability and substrate and site suitability.

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